Parametric Musical Sonification for Mixed Reality Stroke Rehabilitation

Isaac Wallis
Arizona State University
699 South Mill Ave. Rm 395
Tempe, AZ, 85281
iwallis@asu.edu

Todd Ingalls
Arizona State University
699 South Mill Ave. Rm 395
Tempe, AZ, 85281
testcase@asu.edu

1.INTRODUCTION

This abstract describes the interactive audio feedback portion of a coordinated submission of posters on mixed reality stroke rehabilitation at Arizona State University. The Mixed Reality Rehabilitation project aims to develop a real-time multimedia system for upper extremity rehabilitation of stroke survivors through task-oriented physical therapy[2]. The poster presentation will include auditory examples of the musical output.

2.MOTIVATION

There are three well-known techniques for using music to overcome sensorimotor deficiencies. Studies show that rhythmic auditory stimulation is useful to improve spatiotemporal aspects of cyclical movement; therapeutic musical instrument performance is used for relearning movement and overcoming unhealthy compensation strategies; and patterned sensory enhancement uses harmonic, melodic, and dynamic cues to regulate any or all aspects of functional movement[1]. We decided to design the musical element of our stroke system to make use of all three strategies in order to optimize the upper-extremity kinesthetic rehabilitation of stroke patients.

3.SONIFICATION DESIGN

Stroke patients must perform a number of sets of reaching movements, with ten reaches per set. A foreground instrument—whether piano, marimba, or guitar—plays along with each reach. When the arm is still the notes are regularly-timed in order to establish a rhythm. However, the notes accelerate along with the velocity of the arm when the movement takes place. This mapping is designed to encourage kinesthetic smoothness: If the patient reaches smoothly, the sonification will produce an even acceleration/deceleration phrase, but any jerkiness in the movement will produce short bursts of notes. A chord progression is mapped to spatial zones along the reaching pathway, and while the patient's hand occupies a zone all notes will be selected from the tones of that chord. If the patient performs a successful reach, a bell-like sound indicates success. When the patient returns to the rest position the trial ends with a fade-out; the next trial begins a few seconds later.

Certain aspects of the sonification are optional and enabled only when there is a need to target specific aspects of the movement. For example, if we want to improve the spatial variance of the patient's movement, there is a feature which detunes all pitched notes if the patient travels outside the hull. Similarly, if we want to encourage a wider extension of the elbow, we can turn on a background orchestra sound whose volume is mapped to the elbow angle.

Patients often develop unhealthy compensation habits to assist their reaching movements. With stroke patients who have decreased arm strength, two common compensation habits are: (1) torso compensation, in which the patient leans or positions their body in order to minimize reaching distance; and (2) shoulder compensation, in which the patient raises or contorts their shoulder in order to use their stronger back muscles to assist the reach. We can enable compensation warning indicators to alert the patient to these compensation problems. For torso compensation, we use a clattering sound; for shoulder compensation, we use a noisy cymbal-roll sound. Both indicators swell along with the degree of compensation.

4.RESULTS

We have shown that patients perform swifter and smoother reaches, with less path variance and compensation, after using our system. All of these movement features were specifically targeted in the sonification design. However, since the music is only one element in a very complex system there are no objective or quantifiable measurements determining, as of yet, the sonification's effectiveness within the system.

5.UPCOMING RESEARCH: MUSICAL EMOTION

In a separate experiment, we were able to design an interactive music generator to influence the perceived musical emotion of the output[3]. There are plans to incorporate elements of that system into this stroke sonification. The benefit of using the music to communicate emotion is that it gives us some power over physiological responses. For example, in our stroke system we have discovered a need to communicate feelings of calm because tenseness adversely affects patient movement.

6.REFERENCES

[1] Thaut, M. 2005 Rhythm, Music, and the Brain. Routledge.

[2] Wallis, I., Ingalls, T., Rikakis, T., Olsen, L., Chen, Y., Xu, W., and Sunadaram, H. 2007 Real-Time Sonification of Movement for an Immersive Stroke Rehabilitation System. In Proc. of the 13th Int. Conf. on Auditory Display (Montreal, Canada, June 26-29, 2007), 497-506.

[3] Wallis, I., Ingalls, T., and Campana, E. 2008 Computer-Generating Emotional Music: The Design of an Affective Music Algorithm. In Proc. of the 11th Int. Conf. on Digital Audio Effects (DAFX-08, Espoo, Finland, Sep. 1-4, 2008)